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Prior knowledge of the content of a passage should reduce the effort required to encode the passage, and facilitate its recall. The results of two experiments on the effects of prior knowledge upon comprehension of simple technical prose are presented. The procedure was to collect ratings of the amount of prior knowledge for individual passage sentences, and then determine whether those familiarity ratings predict reading (study) time and recall for the sentences. Results are patterned on the idea that increased study time is required for unfamiliar material due to the additional processing required to encode an unknown proposition and to elaborate less familiar propositions. The results are discussed in terms of possible theoretical mechanisms for the use of prior knowledge in prose memory. (Author/PN)

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The Role of Prior Knowledge in the Comprehension of Simple Technical Prose

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Abstract

Prior knowledge of the content of a passage should reduce the effort required to encode the passage, and facilitate its recall. This paper presents the results of two experiments on the effects of prior knowledge upon comprehension of simple technical prose. The basic procedure was to collect ratings of the amount of prior knowledge for individual passage sentences, and then determine whether those familiarity ratings predict reading (study) time and recall for the sentences. The first experiment showed facilitating effects of prior knowledge on study time, but only a very weak effect on recall. The second experiment assessed whether the lack of a recall effect was task-specific. Three encoding task conditions were used in the same basic procedure: a self-paced study task, a force-paced study task, and an incidental learning task. A cued recall test followed each condition. In the self-paced task, readers studied unfamiliar material longer than familiar material, but recalled at the same level regardless of familiarity. In contrast, familiarity did predict recall in the force-paced and incidental tasks. Unknown propositions were recalled less often than known propositions; the recall of unknown propositions was especially low in the incidental task. An explanation for this pattern of results is based on the idea that increased study time is required for unfamiliar material due to the additional processing required to encode an unknown proposition and to elaborate less familiar propositions. In the self-paced task subjects adjust study time according to the degree of unfamiliarity to achieve a constant level of recall, resulting in weak or absent recall effects. In the force-paced task, the encoding and elaboration processes are constrained by time, resulting in poorer recall for unfamiliar material. In the incidental task, the encoding and elaboration processes were not strongly engaged, and so recall of novel information was very poor. The results are discussed in terms of possible theoretical mechanisms for the use of prior knowledge in prose memory.

The Role of Prior Knowledge in the Comprehension of Simple Technical Prose

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We all have the strong intuition that a person should be able to learn and remember material better if the person has a lot of prior knowledge about the content of the material. This issue has great practical importance in understanding how people learn technical material from textbooks and how they use technical documents such as maintenance manuals. However, the experimental literature documenting the relationship between content familiarity and prose memory performance is sparse, and the available results somewhat contradictory. There are few studies presenting direct evidence that in a prose memory situation, prior knowledge of the subject matter facilitates study and memory for passage content. Spilich, Vesonder, Chiesi, and Voss (1979) found that subjects who were very familiar with the terminology, rules, and procedures of baseball recalled important facts about a baseball game much better than subjects who were relatively unfamiliar with baseball. J. R. Anderson (1981) found that subjects given prior knowledge about individuals learned new information about the individuals faster, but retrieved this information more slowly. Graesser, Hoffman, and Clark (1980) found a slight facilitative effect of prior knowledge on reading times, but in another experiment, Graesser, Hauft-Smith, Cohen, and Pyles (1980) found that prior knowledge can in fact have a detrimental effect on recall.

Mechanisms of Prior Knowledge

Despite the lack of experimental study of prior knowledge, the theoretical issues are very clear. There are three explanations for why prior knowledge should facilitate study and recall of prose material.

Schema transfer. One approach is that if a reader has the appropriate schema for the passage content, facilitation of study, as well as retrieval, should occur. If a schema is viewed as an organized knowledge structure which guides perception (Rumelhart, 1979), we would expect encoding time to be reduced. Since the structure for encoding the material is already present, the reader can simply instantiate the schema with the to-be-encoded material. Remembering from a schematic knowledge base can be viewed in much the same way. Rumelhart and Ortony (1977) suggest that remembering can be thought of as perceiving with memory as the modality. In this way a schema could also be a guide for recall. Hence, prior knowledge of a relevant schema should facilitate prose memory performance (cf. Graesser, Hoffman, and Clark, 1980).

But the relevancy of schematic knowledge to technical prose has not yet been established, and it can be argued that schemas have only a weak role in technical prose (Kieras, in press-b). Schemata are usually described in terms of stereotypical sequences of events, which appear in simple stories (e.g., Graesser, 1981), goal directed activities (e.g., Spilich, Vesonder, Chiesi, & Voss, 1978), or the plot structure of a story, independent of passage content (e.g., Thorndyke, 1977). These types of prose are quite different from technical prose, which is often simply an exposition of facts about a subject, and which often does not include a temporal sequence of events or a goal. Thus it appears that schematic knowledge is not necessarily applicable to technical prose. This conclusion is supported by Graesser, Hoffman, and Clark (1980), who found that rated narrativity strongly predicted recall of passages, and that technical passages were very low on this dimension.

Elaboration. Another theoretical approach to explaining the role of prior knowledge is the concept of elaboration (Anderson & Reder, 1979). During study, additional relationships interconnecting the concepts are inferred and added to the memory structure, resulting in alternate retrieval paths that facilitate recall. Familiar material should be easier to encode and remember than unfamiliar material because there is information already present in memory to serve as a basis for elaboration. Furthermore, highly familiar information may already have many alternate retrieval paths already present, since the concepts involved would already be highly interconnected in the memory structure. Thus the effort required to perform elaborative processing on familiar material should be easier and quicker than for unfamiliar material.

There is support in the literature for effects of prior knowledge on elaboration (see Gagne, 1978). For example, Johnson (1973) found that linguistic units rated high on meaningfulness were recalled better than those rated low on this dimension. Meaningfulness was measured as in the traditional verbal learning measure m, as being the ease with which a linguistic unit could call forth associations with past experience. Assuming that meaningfulness is a measure of prior knowledge, it appears that recall is aided by pre-existing knowledge. However, there are methodological problems in the Johnson study. Subjects were instructed to rate phrases that aroused sensory imagery as highly meaningful. But high imagery material has been shown to be recalled better than low imagery material (Paivio, 1971), and the memory effects related to m-value have been shown to be due to imagery value. So, the better recall for highly meaningful prose material may actually be an effect of imagery value. Hence, although elaboration is a possible explanation for the role of prior knowledge in facilitating recall, this mechanism has not yet been directly demonstrated.

Representation saving. Another explanation, offered here, is that prior knowledge works on a proposition-by-proposition basis by saving on the amount of representation building performed

during comprehension. That is, if the reader already knows an individual proposition, the encoding effort to put it into memory is either unnecessary, or will be greatly reduced. In more detail, before an input proposition is stored in long-term memory, a check is done to see if the proposition is already present. If so, then the memory representation for the proposition does not need to be constructed again; rather the pre-existing representation only needs to be tagged to represent its appearance in the specific passage. In contrast, if an input proposition is unknown, a representation for it has to be built from "scratch", and then tagged. This mechanism has been used in several simulation models of comprehension and memory, such as those of Anderson and Bower (1973) and Kieras (1977). This hypothesis yields the straightforward prediction that some measure of encoding effort, such as study time in a self-paced presentation situation, should be related to the number of passage propositions that the reader already knows. Furthermore, propositions already known should be recalled better, since they would require less encoding effort for successful recall.

Clearly, the predictions of the representation-saving hypothesis do not differ at the gross level from those implied by the elaboration hypothesis, but the specific emphasis is different. The elaboration hypothesis predicts an indirect effect of prior knowledge, in that prior knowledge <u>related to</u>, but not the same as, the to-be-remembered proposition is responsible for facilitation of study and recall. In contrast, the representation-saving hypothesis is that an important effect of prior knowledge is a <u>direct</u> one, in that prior knowledge of the specific to-be-remembered proposition facilitates study and recall.

<u>Methodological Approach</u>

Despite the obviousness of the predicted effects of prior knowledge, demonstrating them presents some severe methodological problems, which perhaps accounts for the unclear state of the literature. It would seem that the ideal experiment on the role of prior knowledge in prose memory would be a transfer design, in which the amount of prior knowledge possessed by the subject would be mainipulated experimentally. This could be done by having subjects learn passages containing different items of knowledge, and then testing for specific transfer effects on a set of passages studied later. We have done a pilot study in this manner, and have come to the conclusion, supported by recent results in the literature (e.g., Anderson, 1981), that such experimentally-acquired knowledge does not have the same properties as true pre-experimental knowledge.

Another obvious approach would be the customary one of getting normative ratings for a set of materials, and then choosing some that are high in content familiarity, and some that are low, and comparing performance on them. But this approach ignores the considerable amount of between-subject variation in background knowledge, and discards much of the information in the

familiarity variable. Eliminating certain obvious confounds would also be extremely hard with this approach. For example, material that is generally less familiar to the typical subject can easily involve more complex sentences and rarer words.

To avoid the problems associated with simple high-low manipulations and experimental training of prior knowledge, a quasi-experimental approach based on multiple regression analysis was used in the studies reported here. Since true pre-experimental knowledge cannot be manipulated directly, it was manipulated, in effect, by choosing materials that vary widely in their familiarity to typical subjects, and by allowing the sampling of subjects to further vary the familiarity at the level of individual subjects. Testing for the effect of familiarity then involves determining whether familiarity predicts study time or recall, with other factors being statistically controlled in the regression analysis.

This approach has important features: (1) It uses all of the information available in the familiarity variable. (2) It provides statistical control for confounded properties of the material, such as word frequency and sentence length. (3) In order to make use of the fact that individual subjects differ in their knowledge, an assessment of prior knowledge was obtained from each subject, along with the performance measures of study time and recall. These variables can then be related to each other at the level of individual subjects. (4) Since the materials vary widely in content familiarity both within and between passages, each individual subject reads and recalls sentences covering a large span of familiarity. Thus, the variation in familiarity has a large within-subject component. This is important because there could be general correlations in the subject population that mimic the desired within-subject effect of prior knowledge. For example, an apparent correlation between study time and familiarity could simply be due to the fact that more knowledgeable subjects are faster readers, and not because of any interesting theoretical mechanism involving prior knowledge. Rather than attempting to equate subjects on variables such as reading ability, analyses were performed in which the between-subject variation is removed statistically, so that only within-subject variation is present.

Experiment 1

In this experiment a set of passages were used in a self-paced presentation procedure, and measures of rated familiarity, study time, and recall, were obtained at the level of individual subjects' processing of individual sentences. The subjects read each passage twice, first in order to rate how much of the sentence content they knew prior to the experiment, and then in order to study for later recall. The question was whether rated familiarity would predict study time and recall, with possible confounded variables statistically controlled. An additional manipulation concerned the presence of an explicitly stated main idea. In work presented in Kieras (in press-a, in

press-b), an explicit main idea was found to have strong effects on the macrostructure-building process, which in turn should strongly influence recall (see Kintsch & van Dijk, 1978; Kieras, 1981b).

Method

Materials. The passages were the four studied in Kieras (in press-a) and are shown in Tables 1-4. The passages were designed to vary in familiarity both within and between passages, and appeared in two versions. Version 1, the good version, had an initial topic sentence that stated a main idea generalization. Version 2, the bad version, was identical to version 1, except it did not contain the first sentence. The number of sentences per passage varied from eight to fourteen. A propositional analysis was prepared for each passage, based on Bovair and Kieras (Note 1). The number of propositions per sentence ranged from one to twelve. For each passage a keyword was selected as a recall cue. An additional passage was prepared for use as a practice passage.

Design. Each subject read and responded to all four passages, two in the good version, and two in the bad version. The assignment of passages to versions was done at random for pairs of subjects, so that for an even number of subjects, each passage appeared equally often in both versions. The order of the presentation of the passages was randomized for each subject.

Subjects. Seventy-two male and female undergraduate students at the University of Arizona were used, and received either two dollars or extra credit points for their participation. The subjects were recruited from introductory psychology classes and an advertisement in the student newspaper. Four subjects had to be dropped because they failed to follow instructions, writing their recall at the wrong point in the experiment, giving a total of 68 subjects.

Apparatus and Procedure. A laboratory computer was used to generate the random presentations, present the passage sentences on video terminals, and record the response data. Subjects were run in groups of one to three.

The subject was seated at a video terminal, and given written instructions for the entire experiment. The subject first rated each of the sentences in each passage for content familiarity. The passages were presented on the video terminal, one sentence at a time, with a rating scale underneath the sentence. A brief verbal description of each point of the scale appeared underneath the scale, which ranged from 1 - 7, with the 1 described as "I know none of it", and the 7 described as "I know all of it". The subject was instructed to choose a rating based on how much of the information in the sentence they knew before the experiment. As soon as the subject typed in the rating of a sentence, the computer displayed the next sentence. The computer recorded the rating of each sentence, and the rating time, which was how long each sentence remained on the screen. After all of the passages

had been rated, the subject then studied each passage, under instructions that the passage was to be recalled later. The passages were presented one sentence at a time in the same order as they appeared in the rating task. The subject tapped the space bar to have the next sentence displayed. The subject was permitted to rest between passages if desired. The computer recorded the study time, defined as how long each sentence remained on the screen.

After studying all passages, the subject wrote his or her recall on a note pad. The computer displayed a keyword from each passage as a cue for recall. The cues were presented one at a time in the same order as they were seen in the rating and study tasks. The subject wrote his or her complete recall of one passage before tapping the space bar to obtain the next cue. The instructions specified that they were to write all they could remember about each passage, but their recall did not have to be verbatim.

Results

The recall protocols were scored blind, without knowledge of the original passage version condition. Each protocol was scored independently by two judges, and a third judge then reconciled any discrepancies between the two scorings. The scoring criterion was strict, with only exact reproductions of the passage propositions, and synonyms, allowed (see Bovair and Kieras, Note 2). The proportion of propositions recalled for each subject on each sentence was determined.

Multiple regression analyses were performed on the data consisting of each subject's responses to each sentence on all four passages, yielding a total of 2992 data points. It should be kept in mind that between-subject variability was not removed or accounted for in these analyses, resulting in a fairly low proportion of the variance being accounted for. An analysis was done with study time (STUDYTIME) as the dependent variable, and another for recall (RECALL) as the dependent variable. The predictor variables available to the stepwise regression procedure were the familiarity rating (FAMILIARITY), the number of words in the sentence (WORDS), and the mean of the Standard Frequency Index values for each word in the sentence (FREQ). The Standard Frequency Index is taken from Carroll, Davies, and Richman (1971), and is equal to $10(\log f + 10)$, where f is equal to the frequency of occurrence of a word in their corpus. Since the first sentence in a passage usually requires a disproportionately large study time (see Kieras, 1981a, in press-a, in press-b), a dummy variable, FIRST, indicating whether the sentence was the first of a passage, was defined. A second dummy variable, VERSION, was included to test for an effect of the passage version.

The results of the regression analyses on STUDYTIME are shown in Table 5 and those for RECALL in Table 6. The tables show the step on which each predictor variable was entered, and the increment in R^2 at each step. The coefficients shown are those

in the final equation that includes all variables that entered. The F-ratios are the "F-to-remove" and so provide a test of significance of the coefficients in the final equation. Finally, the standardized regression coefficients allow comparisons of the importance of each variable independently of scale differences.

As shown in Table 5, about 7% of the variance in STUDYTIME was accounted for by the final equation. The standardized regression coefficients show that WORDS was the most important factor in determining STUDYTIME, followed by FREQ, FAMILIARITY, and FIRST. As the number of words in a sentence increased, study time increased, while higher familiarity and higher frequency words decreased study time. The unique contribution of WORDS was about 1% of the variance in study time; FAMILIARITY uniquely accounted for almost 3% of the variance, and FREQ a little over 1%. FIRST entered the equation for STUDYTIME, but accounted for only an extremely small amount of the variance. However, VERSION failed to enter the equation at all.

The analysis of RECALL is shown in Table 6; almost 4.5% of the variance is accounted for. WORDS was again the most important variable in predicting RECALL, with longer sentences being recalled poorly. Higher FREQ also decreased RECALL, while FAMILIARITY increased RECALL slightly. FAMILIARITY and VERSION accounted for only a small amount of the variance. Familiarity can be seen to play a more important role in study time than it does in recall by comparing the standardized regression coefficients for FAMILIARITY in Tables 5 and 6. The standarized regression coefficient of FAMILIARITY for study time is -.145, while it is only .048 for recall. Thus, familiarity can be seen to play a more important role in determining how long a sentence is studied than it does in determining level of recall.

Discussion

The results of Experiment 1 indicate effects of familiarity on both study time and recall, but the recall effect is extremely weak. The obvious prediction that prior knowledge would increase recall was barely obtained. A straightforward explanation for this result is that subjects could have used a strategy of adjusting their study time based on the sentence familiarity, in order to achieve a desired level of recall. Thus, subjects did not study all of the sentences for the same amount of time, but rather studied unfamiliar sentences for longer periods of time, and then recalled all material at about the same level. The result is a definite study time effect, about .8 seconds less time for each point on the familiarity scale, but a very weak recall effect of about .7% more recall for each point on the scale.

Experiment 2

The second experiment was designed to confirm the hypothesis suggested by Experiment 1. If subjects were adjusting their study time based on familiarity in order to obtain a constant recall level, then by holding study time constant, recall should depend on familiarity. Alternatively, if subjects did not know that they would be tested for later recall, they would not adjust their study time, and so familiarity effects on recall should also appear.

Thus, familiarity effects were studied in three conditions: a self-paced condition, identical to the procedure used in Experiment 1; a force-paced condition, with study time held at a predetermined level for each subject and each sentence; and an incidental condition in which subjects did not know they were to recall the passages later. In the force-paced condition the amount of study time allowed on a sentence was the time that the same subject had taken to rate the same sentence for content familiarity. This provided a simple way to adjust the permitted study time to an amount tailored to both individual sentences and individual subjects. Using the rating time was justified since in Experiment 1, the rating time was found to be unrelated to the rating itself, and also unrelated to study time. Thus, the rating time provides a measure of how long it takes to read and comprehend a sentence, but should not be long enough to allow much memorization of an unfamiliar sentence. Subjects in the incidental learning task did not study the sentences after rating them for content familiarity, and were not told there would be a final recall test. Instead, they rated the sentences a second time, for importance of each sentence to the subject's perceived main idea of the passage, and then were given the recall test. This importance measure was also used as a predictor variable.

The familiarity rating method employed in Experiment 1 seems to be a logical choice for assessing an individual's familiarity with the content of a sentence, but it is a very subjective measure, and has not been validated. Experiment 2 included an objective multiple-choice test designed to give an assessment of prior knowledge at the level of a subject's knowledge of the individual propositions in the passages.

Finally, since the version manipulation in Experiment 1 produced no study time effect, and only a very weak effect on recall, it was not included in this experiment; only good versions were used.

Method

Materials. The good versions of the four passages and the practice passage used in Experiment 1 were modified so that all passages were eight sentences long. The passages are shown in Tables 7 through 10.

The knowledge test was carefully constructed to test for knowledge of specific propositions without giving the subject much information in the course of taking the test. The test contained 82 multiple-choice questions, the first two being practice. Fifty-five of the questions tested for one or more specific propositions, with the remaining questions being fillers. It was not possible to test for knowledge of all of the passage propositions, because it is necessary to state some propositions in the questions, and other propositions are essentially impossible to test without stating an excessive number of other propositions. Some of these untested propositions were judged to be known to all subjects, while others were judged to be unknown. In the test, 66% of the propositions in the passages were explicitly tested; 27% were untested and assumed to be known by all subjects; the remainder were untested and assumed not to be known by any subject.

The written instructions for the three task conditions were composed so that all subjects received the same instructions for common portions of the experiment, but would not see any instructions for the tasks in the other conditions, and would not be told of the nature of the study or recall phases of the experiment until the proper time for each condition. The same recall cues were used as in Experiment 1.

Design. The three task conditions were a between-subject manipulation. Similar to Experiment 1, each subject processed all four passages, and provided measures of familiarity, knowledge test answers, study time, and recall. The order of presentation of the passages was randomized for each subject, but this order was the same for the rating, study, and recall portions of the experiment for each subject.

Subjects. Ninety-two male and female undergraduates at the University of Arizona were each paid five dollars for their participation. Subjects were recruited by an ad in the student newspaper, and by signs posted in campus buildings. Two subjects had to be dropped because they wrote their recall at the wrong point in the experiment, yielding a total of 30 subjects in each task condition.

Apparatus and Procedure. The apparatus used was the same as in Experiment 1. Subjects were run in groups of one to three, and were arbitrarily assigned a condition as they arrived for the experiment. All subjects first received instructions for the knowledge test and the familiarity rating task. Each multiple-choice test question was then displayed on the video terminal, and the subject would type in the number of their

answer. When the subject had completed the test, he or she then rated the passages for prior knowledge in the same manner as Experiment 1.

When the subjects finished the rating task, they were given the next set of instructions, which depended on the condition. The self-paced task received instructions explaining that they should study each sentence for as long as desired and that they would recall the passages later. The force-paced subjects were instructed that the sentences would appear on the screen at a predetermined rate, and that they might not be able to study them for as long as they would like, and that they would have to recall later. The incidental learning condition subjects received instructions explaining the importance rating task, and were not told that they would have to recall the passages later. The subjects were instructed to try to discover the main idea of the passage, and as they went along, they were to rate the importance of each sentence to the main idea (see Kieras, in press-a,b). The importance rating task was similar in format to the familiarity rating task, with a seven point scale again being displayed under each sentence. The scale went from 1, "totally irrelevant" to the main idea; to 7, "extremely important" to the main idea. Subjects typed in the number of their rating. When a subject had finished studying, or rating sentence importance, he or she received the instructions for the recall task. This procedure was the same as in Experiment 1.

Results

The passages were propositionalized and scored in the same manner as Experiment 1. The variables used in the regression analyses were the proportion of propositions recalled per sentence (RECALL), familiarity rating (FAMILIARITY), study time (STUDYTIME), the mean Standarized Frequency Index values for the content words in the sentence (CFREQ), the proportion of propositions tested for and known in the sentence (TESTP), and in the case of the incidental condition, importance rating. The mean importance rating of each sentence, collected from subjects in the incidental task, was used as a predictor variable for all conditions (MEANIMP). Study time was analyzed only in the self-paced task condition, because this was the only true study time measure. Study times in the force-paced condition were necessarily the same as the rating times, and study time in the incidental condition is not a true "study time", but rather time taken to rate a sentence for importance.

Test results. Each subject received credit for knowing a specific proposition if he or she correctly answered the test question testing for that proposition. In the case of questions that tested for more than one proposition, credit was given for all of the propositions. The resulting scores showed the individual propositions known and unknown by each subject. The proportion of known propositions in the sentences correlated (r=.571) with the familiarity ratings for the same sentences, indicating that the two variables are to some extent measuring the

same thing. When the propositions that were not directly tested were excluded, the correlation increased substantially (r=.66). This form of the test score was used as TESTP in the regression analyses. Apparently, the familiarity rating is valid as a measure of prior knowledge, but it is possible that it depends to some extent on factors other than prior knowledge.

Another form of the test score results was calculated. This was simply the number of propositions in each sentence that the subject was tested on and knew, according to the test score. This variable, KNOWN, was used in conjunction with the number of propositions in each sentence, PROPOSITIONS, to predict FAMILIARITY. In Table 11 is shown the results of the regression analysis using these propositional variables and some of the other sentence properties. As can be seen in the table the FAMILIARITY rating was very strongly related to the number of known propositions in the sentence and inversely related to the total number of propositions in the sentence. The variables FIRST, CONFRQ, and MEANIMP also are related to the familiarity rating. There are two conclusions to be made from this analysis: the first is that TESTP can be considered to consist of the two variables KNOWN and PROPOSITIONS, since these propositional variables contain the same information as TESTP, and are in a theoretical sense more basic than TESTP. The second conclusion is that the familiarity rating is influenced to some extent by variables other than the amount of known information. The first sentence of the passage is rated more familiar; the content word frequency influences the familiarity rating; and the more important sentences were judged to be more familiar. Because of this possible contamination of the familiarity rating, the analyses reported below use both the familiarity rating and the two propositional variables KNOWN and PROPOSITIONS.

Recall analysis using test results. An analysis was performed on the recall data to determine whether propositions classified as known to individual subjects were recalled better than unknown ones, and whether this effect depended on the task condition. The proportions of recalled and nonrecalled propositions classified by test score and condition are shown in Table 12. This contingency table was analyzed with a three-factor log-linear analysis (Reynolds, 1977; Bishop, Fienberg, & Holland, 1975). The factors were task condition, whether a proposition was known or unknown on the knowledge test, and whether the proposition was recalled. Only those propositions that were actually tested for in the prior knowledge test were included. The analysis showed that the saturated model was necessary to provide a good fit ($p > .05$) to the data; all lower order models had highly significant differences between the data and the fitted model. This means that all main effects and interactions on dependent factors in Table 12 are significant.

The simple main effects are that the probability of recall of a proposition is lower than non-recall, and more propositions were known on the test than unknown. There is a difference in recall between conditions. Recall is low in the incidental condition,

with self-paced and force-paced roughly the same. The key result is that the difference in recall between known and unknown propositions differs between conditions. In the self-paced condition, where subjects could study for as long as they wanted, there is no difference in recall between known and unknown propositions. In the force-paced condition, where subjects could not study as long as they wanted, there is an effect of prior knowledge on recall, with known propositions recalled somewhat more often than unknown propositions. In the incidental condition, recall of known propositions was very similar to that in the other conditions, but recall of unknown propositions was very low.

Recall regression analysis. The first step in the regression analysis of the recall data was to compute a separate regression analysis for each task, with RECALL, the proportion of propositions recalled on each sentence by each subject, being the predicted variable. In the self-paced task, familiarity did not predict recall, replicating the weak effect in Experiment 1. However, familiarity did predict recall in the force-paced and incidental conditions. An analysis of the combined data for all three tasks was then done to test the significance of the interaction of familiarity and condition in predicting recall. These results are shown in Table 13, in the same format as Tables 5 and 6 above. The three task conditions were dummy-coded with the variables INCTASK and FORCETASK, for the incidental and force-paced tasks, respectively, and with the self-paced task taken as the baseline. The interaction variables FAMINC and FAMFORCE, the product of FAMILIARITY and the corresponding task dummy variable, were defined to represent the contribution of familiarity rating that is distinctive to the incidental and force-paced tasks. The main effect variables were forced into the equation first. The final R^2 is .116. Notice that the final coefficient for the main effect of FAMILIARITY is very small, and is not significant, but that both FAMFORCE and FAMINC entered the equation. This pattern means that a specific form of the task by familiarity interaction is significant. Namely, there is no effect of familiarity in the self-paced task, but familiarity does have an effect in the force-paced and incidental tasks. The effect of familiarity is essentially the same in these two tasks; the coefficients for FAMINC and FAMFORCE are not significantly different.

Again, familiarity was not a strong variable; its unique contribution to accounting for variance was only about 2-3%, which is not impressive. Its coefficient shows that every point on the familiarity scale adds about 3% to the percentage of recall.

Between-subject variability was removed by converting each subject's recall score on the sentences into z-scores computed within each subject, that is, based on each subject's mean and standard deviation for recall. This transformation puts all of the subjects on the same scale of recall, removing between-subject differences, but leaving within-subject variation. As shown in Table 14, the regression on Z-RECALL yields the same predictors,

with very similar standardized regression coefficients, as the analysis on raw RECALL in Table 13. Thus, general correlations do not account for the role of prior knowledge; it appears within subjects.

As a side result, notice that the coefficients given to FIRST and MEANIMP are negative, indicating poorer recall for propositions in the first sentence, which states the main idea, and for sentences rated as being important. This is consistent with results noted in Kieras (1981b), in that standing in the macrostructure is not the only determinant of recall. However, more detailed analysis would be required to determine if this effect is actually due to poor recall of just the unimportant, "detail" propositions in important sentences.

Study time. The multiple regression analysis of STUDYTIME is shown in Table 15. This analysis predicts study time in the self-paced task, for each subject on each sentence, as a function of the subject's familiarity rating for each sentence, and the properties of the sentence itself. These results replicate Experiment 1. The study time for each sentence is predicted by the number of words in the sentence, the familiarity rating, the mean of the Standardized Frequency Values values for the content words in the sentence, and the mean importance rating of each sentence to the main idea. This analysis used all 960 points in the data (N=960), and accounts for 19% of the variance in study time, but without removing any of the between-subjects variability. This was done in the analysis on the within-subject z-transformed study times shown in Table 16. The equation is very similar to the raw data analysis, but 30% of the variance is accounted for. Notice the similarity in standardized regression coefficients for FAMILIARITY in between Tables 15 and 16, showing that the effect of prior knowledge is within-subject.

Although the effect of familiarity was present, it was small. Familiarity rating uniquely accounts for only about 4% of the variance; this is comparable to the results of Graesser, Hoffman, and Clark (1980). Each point on the familiarity scale corresponds to about a .4 second decrease in study time.

The study time on each sentence was also analyzed using the propositional variables described above and the results are shown in Tables 17 and 18. An immediate result is that only the two propositional variables, PROPOSITIONS and KNOWN, entered the equation. The other variables that appear in the Table 15 analysis were strongly nonsignificant ($p>1$). But in spite of only two predictor variables entering the equation, the proportion of variance accounted for is very similar to the analyses shown in Tables 15 and 16. This suggests that the effects due to FAMILIARITY, WORDS, and the other predictors are actually due to their correlation with the propositional variables This result agrees substantially with the results of Kintsch and Keenan (1973) and Kieras (1981a) that reading times are mostly a result of processing time on individual propositions. This time is here estimated at about .8 seconds per proposition. But if there are

known propositions in the sentence, about .7 seconds of processing time per proposition is saved.

Discussion

The results of Experiment 2 agree with those of Experiment 1. In Experiment 1 there was a relationship between familiarity and study time that accounted for a constant level of recall across familiarity. This result was replicated in Experiment 2, in that familiarity was not a predictor of recall in a self-paced study task, while it was a predictor of recall in the force-paced and incidental tasks. This was demonstrated by the results on the recall of specific propositions that were known or unknown on the knowledge test, and by the significant interaction in the regression analyses.

In the self-paced task, subjects could study unfamiliar sentences for as long as they felt necessary, hence the lack of a familiarity effect in recall. Subjects in the force-paced task, who could not spend additional time on an unfamiliar sentence, recalled familiar material at a higher rate than unfamiliar. The effects of prior knowledge are strongest in the incidental task, where recall was 70% higher for previously known propositions than previously unknown ones, although the average level of recall was lower than that of the other conditions.

The second objective of Experiment 2 was to validate the content familiarity ratings as a method of prior knowledge assessment. Although the correlation between FAMILIARITY and either TESTP or KNOWN is not extremely high, it is acceptable for a rating scale measure. This is important methodologically, since the rating scale measure is considerably more convenient than the knowledge test.

General Discussion

Explaining Familiarity Effects

The elaboration hypothesis can give a plausible account for the pattern of effect of prior knowledge. According to this hypothesis, familiarity with the sentence being studied implies that some retrieval paths for the sentence information should already exist, and more should be easy to construct, because there would be a rich supply of related information in memory. Thus, a minimum amount of effort should be needed to encode very familiar material. More processing time should be needed to encode unfamiliar information, because more retrieval paths would have to be built, and a more extensive search of memory would have to be performed to find information that can be used to build elaboration structures.

The success of later recall depends on the amount of elaboration that was accomplished during study. The self-paced task allows the subject to spend as much time as needed to adequately elaborate either familiar or unfamiliar sentences. The

force-paced task does not allow quite enough time for unfamiliar content, and in the incidental task, the subject engages in little elaboration, producing much lower recall. However, notice that in this condition, known information was recalled much better than unknown and at about the same level as in the other tasks, which presumably require elaboration. If differential elaboration is the sole explanation for prior knowledge effects, it has to be explained why subjects who are not required to elaborate will perform as much on familiar sentences as subjects who are required to do so, but still do very little on unfamiliar sentences.

The representation-saving hypothesis for the role of prior knowledge also provides a plausible explanation. If a proposition is known, it need only be tagged, and no new representation built in memory. An unknown proposition would take more study time, because the representation would have to be both built and tagged. If this time were restricted, as in the force-paced task, a lower level of recall for an unknown proposition, compared to known proposition, results because there is not enough time to complete the encoding process. Similar effects would appear in the incidental task, because the subject will not try very hard to build the complete long-term memory representations required for recall. So, unfamiliar material, which requires both building and tagging, is quite likely to be completely unremembered, while familiar material, which only requires the tagging process, might be remembered just as well as in an intentional memory task. Notice that this hypothesis seems more compatible than the elaboration explanation with the stronger effect of prior knowledge in the incidental task compared to the other tasks.

A Combined Model

The representation-saving account of prior knowledge and the elaboration account are not necessarily incompatible. A model incorporating both mechanisms can be offered as an explanation for the effects of prior knowledge. This model states that as a reader encounters a proposition, a check is performed in long-term memory to see if the proposition is already represented. If it is, it can simply be tagged as seen in this context. If it is not already present in long-term memory, the representation must be built, and then tagged. At this point there should be an increase in processing time for unfamiliar material, compared to familiar, both because of the need to build the new representation and also because the search for a non-represented proposition will probably take longer than a search for a proposition already in LTM.

Once a representation has been located or built, and then tagged, elaboration can be done if the subject is processing the propositions for the purpose of later recall. The elaboration process is performed until some criterion of predicted recall success is reached. Familiar material should also take less time in this stage, since there are probably some redundant retrieval paths already present in long-term memory, and there is more related knowledge to support the inference of new paths.

Thus, the recall and processing time effects of prior knowledge in these results can be attributed to the joint effects of both representation saving and elaboration. The differences between the intentional and incidental task conditions are a result of the elaboration process being heavily engaged in intentional tasks, but not the incidental task.

Relation to Schema Theory

Although the above arguments and results downplay the role of schemata in technical prose, they should not be seen as incompatible with schema theories in general. In prose for which a reader has a relevant schema, the search of memory for a previously-known proposition should procede faster, because the schema should guide the search efficiently. If a schema is applicable to the material, many of the propositions may already be implicitly or explicitly represented in the schema itself, reducing the amount of structure to be built, and providing many elaborative interconnections as well. Hence, the facilitative effects of prior knowledge at the schema level could actually consist of effects at the levels of elaboration and representation saving.

The Weakness of Familiarity Effects

An important final conclusion that should be pointed out is that the effect of prior knowledge in these results is not very strong. The proportion of variance accounted for by prior knowledge is fairly low, only a few percent. This seems counterintuitive. The materials used have drastic differences in the amount of information individual subjects already knew. However, there is no corresponding drastic difference in study time, nor is there much difference in probability of recall in an intentional recall task. It would certainly seem obvious that if one already knows the material, very little effort should be required to recall it, and recall should be very good. This is the obvious intuition, but the intuition seems to be false. How can this weak effect of prior knowledge be explained?

A good explanation is based on the nature of the prose memory paradigm and how a typical subject will approach it. In prose memory experiments subjects are asked to study and then recall something within a short span of time, roughly an hour. It could be that a typical subject, being a college student, is very good at taking information that is not very familiar, or perhaps not even meaningful, and putting it away into memory in order to recall it again in the near future. This efficient strategy for comprehension and memory could be termed a "garbage processing" skill. Notice that it would be especially useful with technical material that does not follow a good schema. If subjects have this skill, which seems likely given what they do in their college courses, the result would be a tendency for unfamiliar material to be processed very similarly to familiar material, swamping the strong familiarity difference that should be there. Thus, it does not make much difference in processing time or recall whether the

subjects already know the specific facts in the passage or not. This hypothesis is confirmed by the strong prior knowledge effect on recall in the incidental task, where presumably the subjects' "garbage processor" encoding strategy is not engaged.

This conclusion suggests that in order to study the role of prior knowledge in comprehension, tasks must be used that do not engage the "garbage processing" strategy. Perhaps there are some ecologically valid reading and memory tasks that are strongly dependent on prior knowledge, but it appears that the standard prose memory task is not such a task.

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Table 1
The METALS passage, Experiment 1

1.	[Different cultures have used metals for different purposes.]
2.	The ancient Hellenes used bronze swords.
3.	The ancient Greeks used copper shields.
4.	The Hellenes invaded ancient Greece before the Trojan War.
5.	The bronze weapons that were used by the Hellenes could cut through the copper shields that were used by the Greeks.
6.	Because the color of gold is beautiful, the Incas used gold in religious ceremonies.
7.	The Incas lived in South America.
8.	However, the Spaniards craved the monetary value of gold.
9.	Therefore, the Spaniards conquered the Incas.
10.	Because aluminum does not rust and is light, modern Western culture values aluminum.
11.	Aluminum is used in camping equipment.
12.	Titanium is used in warplanes and is essential for spacecraft.
13.	Warplanes are extremely expensive.
14.	Titanium is the brilliant white pigment in oil paints that are used by artists.

Table 2
The TIMEKEEPING passage, Experiment 1

1. [Modern timekeeping devices are extremely accurate.]
2. An inexpensive quartz-crystal watch has one-second accuracy for several weeks.
3. Proper adjustment of the watch can improve the accuracy.
4. An atomic resonance clock can achieve nano-second accuracy for several years.
5. The theory of relativity predicts that tiny distortions of time would be produced on a long trip in a commercial airliner.
6. Because atomic resonance clocks are very accurate, they could measure the tiny distortions of time and confirm the theory.
7. A hydrogen maser clock has pico-second accuracy for 10 million years.
8. A hydrogen maser clock is used today by the National Bureau of Standards.

Table 3
The INSTRUMENTS passage, Experiment 1

1. [Because keyboard instruments have different mechanisms, the performer can control different aspects of the sound of the instrument.]
2. The clavichord is the oldest keyboard instrument.
3. The clavichord has a small metal hammer at the end of the key.
4. When the hammer strikes the string, the string vibrates between the hammer and the bridge.
5. Since the key is in direct contact with the string, the player can control the pitch.
6. The harpsichord has a small stiff finger that plucks a string.
7. Since the finger always moves through the same distance, the performer can not control the loudness of the sound.
8. Finally, the piano has a hammer that is bounced off a string.
9. The force that is applied by the hammer depends on the force that is applied to the key.
10. This means that the performer can control the loudness of the individual notes.
11. Therefore, the piano is the most expressive instrument.

Table 4
The CARS passage, Experiment 1

1. [Different automobiles are selected by people who prefer different features.]
2. Imported luxury cars are expensive and have advanced design.
3. They are owned by people who are wealthy and appreciate sophisticated cars.
4. They often have electronic fuel injection systems that are controlled by analog computers.
5. Because domestic station wagons are roomy and comfortable, they are preferred by people who have large families.
6. The original station wagons had bodies that were mostly made of wood.
7. The pickup is a small open truck that can carry a large amount of cargo and is preferred by many people who live in rural areas.
8. Since compact cars are small and have small engines, they give good gas mileage.
9. This means that people who commute like compact cars.
10. Most compact cars are made by foreign manufacturers.
11. Because gasoline was cheap, the first American compact car was a failure and caused the bankruptcy of the manufacturer.
12. Since sports cars are tiny and fast, people who enjoy driving like sports cars.
13. Until the Corvette appeared, all sports cars were imported.

Table 5

Regression Analysis on Study Times (N=2992)

Variable	Step	Final Coeff.	Final Std. Coeff.	R^2	F	
CONSTANT		45.450				
FAMILIARITY	1	-.815	-.145	.0294	65.58	**
WORDS	2	.620	.218	.0417	103.94	**
FREQ	3	-.564	-.170	.0659	60.62	**
FIRST	4	3.167	.065	.0697	12.40	**

** Final regression coefficients significant at $p < .01$

Table 6

Regression Analysis on Proportion of Recall (N=2992)

Variable	Step	Final Coeff.	Final Std. Coeff.	R^2	F	
CONSTANT		.8990				
WORDS	1	-.0102	-.146	.0376	45.48	**
FREQ	2	-.0066	-.081	.0412	13.99	**
FAMILIARITY	3	.0066	.048	.0433	6.94	**
DVERS	4	.0291	.042	.0450	5.53	*

** $p < .01$; * $p < .05$

Table 7

The METALS Passage, Experiment 2

---

1. Throughout history, man has used metals for many purposes.
2. The ancient Hellenes used bronze swords.
3. The Hellenes invaded ancient Greece before the Trojan war.
4. The Incas lived in South America.
5. The Incas used gold in religious ceremonies.
6. The Spaniards conquered the Incas for their gold.
7. Aluminum is used in camping equipment.
8. Titanium is the brilliant white pigment in oil paints that are used by some artists.

Table 8

The TIMEKEEPING Passage, Experiment 2

---

1. Modern timekeeping devices are extremely accurate.
2. An inexpensive quartz-crystal watch has one-second accuracy for several months.
3. Proper adjustment of the watch can improve the accuracy.
4. Atomic resonance clocks measure atomic vibrations and they are incredibly accurate.
5. The theory of relativity predicts that tiny distortions of time would be produced on a long trip in a commercial airliner.
6. Atomic resonance clocks could measure the distortions of time and confirm the theory.
7. A hydrogen-maser clock has one-second accuracy for 10 million years.
8. A hydrogen-maser clock is used today by the National Bureau of Standards.

Table 9

The INSTRUMENTS Passage, Experiment 2

---

1. Because keyboard instruments have different mechanisms, the performer can control different aspects of the sound of the instrument.
2. The clavichord has a small metal hammer at the end of the key.
3. Since the key is in direct contact with the string, the player can control the pitch.
4. The harpsichord has a small stiff finger that plucks a string.
5. The player cannot control the loudness of the harpsichord.
6. The piano has a hammer that is bounced off a string.
7. The performer can control the loudness of the individual notes.
8. The piano is the most expressive keyboard instrument.

Table 10

The CARS Passage, Experiment 2

---

1. The design of cars has changed over the years.
2. Luxury cars are expensive and have advanced design.
3. Luxury cars often have fuel injection that is controlled by an analog computer.
4. The original station wagons had bodies that were mostly made of wood.
5. Compact cars are small and have small engines, and they give good gas mileage.
6. People who commute like compact cars.
7. Because gasoline was cheap, the first American compact car was a failure and caused bankruptcy for the manufacturer.
8. Until the Corvette appeared, all sports cars were imported.

Table 11

Regression Analysis of FAMILIARITY
using Propositional Variables

Variable	Step	Final Coeff.	Final Std. Coeff.	R^2	F
CONSTANT		2.0788			
KNOWN	1	1.043	.593	.3050	1692.31 **
PROPOSITIONS	2	-.493	-.358	.4130	632.23 **
FIRST	3	1.303	.169	.4514	113.08 **
CONFRQ	4	.039	.071	.4563	24.90 **
MEANIMP	5	.076	.033	.4571	4.33 *

* $p < .05$; ** $p < .01$

Table 12

Proportion of Previously Known and Unknown Propositions that were Recalled and not Recalled in each Condition of Experiment 2.

		CONDITION		
		SELF-PACED	FORCE-PACED	INCIDENTAL
UNKNOWN	NOT-RECALLED	.57 (741)	.61 (880)	.77 (1057)
	RECALLED	.43 (556)	.39 (564)	.23 (311)
	TOTAL	1.00 (1297)	1.00 (1444)	1.00 (1368)
KNOWN	NOT-RECALLED	.57 (884)	.56 (786)	.61 (905)
	RECALLED	.43 (669)	.44 (620)	.39 (577)
	TOTAL	1.00 (1553)	1.00 (1406)	1.00 (1482)

Note. Raw frequencies are shown in parentheses.

Table 13

Regression Analysis on RECALL for All Tasks (N=2880)

Variable	Step	Final Coeff.	Final Std. Coeff	R^2	F	
CONSTANT		.219				
FAMILIARITY	1	.005	.034	.0220	1.1	
INCTASK	2	-.216	-.263	.0390	42.8	**
FORCETASK	3	-.077	-.094	.0391	5.8	*
FIRST	4	-.189	-.162	.0696	61.8	**
WORDS	5	-.021	-.210	.0962	113.3	**
CONFRQ	6	.010	.115	.1062	34.9	**
MEANIMP	7	-.028	-.079	.1109	15.8	**
FAMINC	8	.026	.167	.1134	15.4	**
FAMFORCE	9	.019	.118	.1161	8.7	*

* $p < .05$; ** $p < .01$

Table 14

Regression Analysis on Z-RECALL for All Tasks (N=2880)

Variable	Step	Final Coeff.	Final Std. Coeff	R^2	F
CONSTANT		-.590			
FAMILIARITY	1	.005	.013	.0200	.2
FORCETASK	2	-.187	-.088	.0201	5.0 *
INCTASK	3	-.310	-.146	.0201	13.1 **
WORDS	4	-.061	-.231	.0543	136.0 **
FIRST	5	-.500	-.166	.0830	63.9 **
CONFRQ	6	.029	.132	.0964	46.4 **
MEANIMP	7	-.077	-.084	.1017	17.6 **
FAMINC	8	.072	.181	.1050	17.9 **
FAMFORCE	9	.048	.113	.1075	7.9 *

* $p < .05$; ** $p < .01$

Table 15

Regression Analysis on Self-Paced Task Study Times (N=960)

Variable	Step	Final Coeff.	Final Std. Coeff	R^2	F	
CONSTANT		6.552				
WORDS	1	.355	.317	.1231	51.2	**
FAMILIARITY	2	-.377	-.227	.1739	94.4	**
CONFRQ	3	-.098	-.108	.1812	11.4	**
MEANIMP	4	.382	.099	.1905	10.9	**

** $p < .01$

Table 16

Regression Analysis on Self-Paced Task Z-Study Times (N=960)

Variable	Step	Final Coeff.	Final Std. Coeff	R^2	F
CONSTANT		.281			
WORDS	1	.123	.464	.233	235.6 **
FAMILIARITY	2	-.082	-.209	.279	50.7 **
CONFRQ	3	-.030	-.141	.292	22.9 **
MEANIMP	4	.106	.117	.305	17.7 **

** $p < .01$

Table 17

Regression Analysis of STUDYTIME in Self-Paced Task using Propositional Variables (N=960)

Variable	Step	Final Coeff.	Final Std. Coeff.	R^2	F
CONSTANT		2.235			
PROPOSITIONS	1	.839	.367	.0949	142.11 **
KNOWN	2	-.705	.240	.1490	60.84 **

** $p < .01$

Table 18

Regression Analysis of Z-STUDYTIME in Self-Paced Task using Propositional Variables (N=960)

Variable	Step	Final Coeff.	Final Std. Coeff.	R^2	F
CONSTANT		-.854			
PROPOSITION	1	+.256	.474	.1659	264.13 **
KNOWN	2	-.188	-.272	.2354	86.87 **

** $p < .01$

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